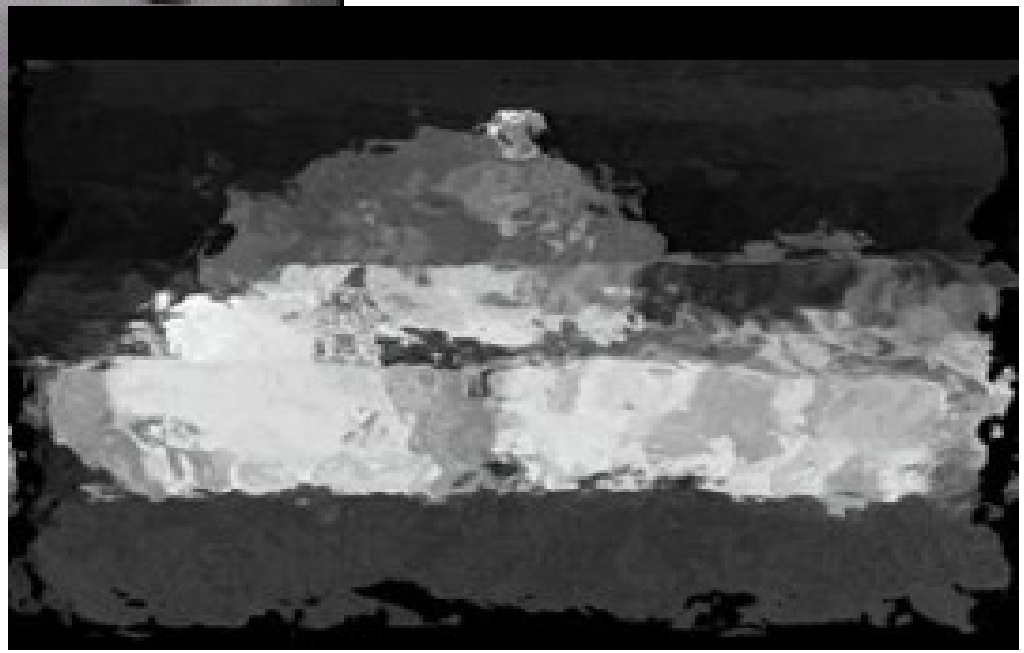
Modeling of Scope Performance in Turbulence

Turbulence
Notes on this briefing

- **The NVTherm model has NOT been developed to address the ansioplanatism. There are no fielded tactical systems with turbulence mitigation exploiting this aspect.**
  - **<u>NVThermIP has limited application to SRVS BAA to:</u>**
    - Demonstrate current day optic technology will support facial ID, BUT NOT in turbulence.
    - Estimate resolution required to perform basic facial ID test (BAA Preps).
    - Use in designing parts of the scope itself, not the processing.
    - NVThermIP will NOT be applied to evaluate the image processing aspect of the SRVS systems or proposed processing concepts.

Turbulence Impacts



Turbulence

- Ultra-narrow field-of-view (UNFOV) camera’s resolution performance can be limited by atmospheric turbulence blur
- Observer Target Acquisition performance is degraded by turbulence blur/distortion
- Short Integration Time blur is instantaneous
- Long Integration Time blur is spot “wandering”

Turbulence

MTF_{turb} model

$$MTF_{short} = \exp\{-57.4a\xi^{5/3}C_n^2\lambda^{-1/3}R[1-\mu(\xi\lambda/D)^{1/3}]\}$$

Where:

a is a wave shape constant (unity for plane wave and 3/8 for spherical)

ξ is the spatial frequency in cycles per milliradian

C_n^2 is index of refraction structure parameter

λ is the wavelength

R is the path length

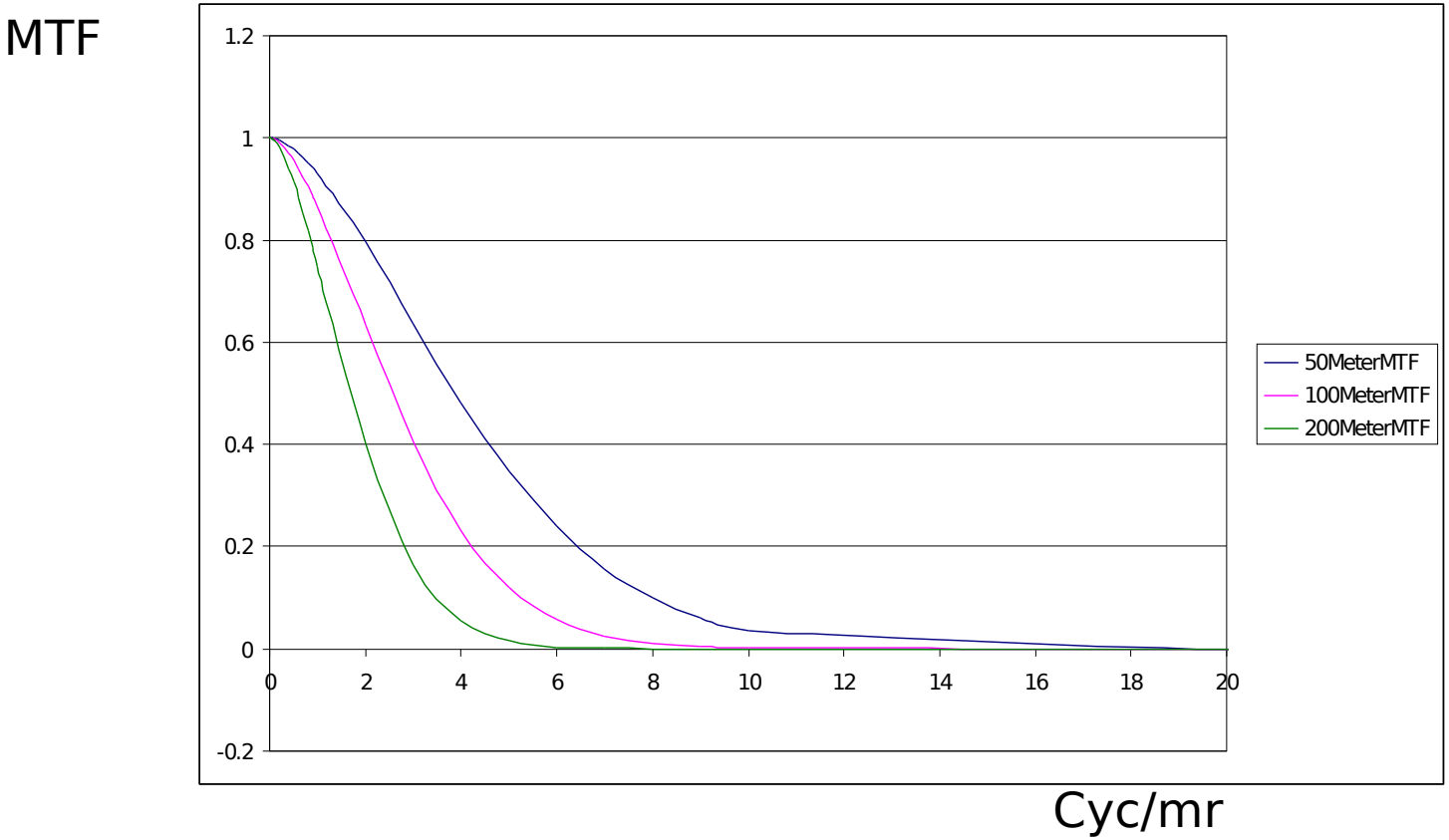
D is the imaging sensor aperture diameter

μ is 0.5 in the far field and 1 in the near field.

Turbulence MTF

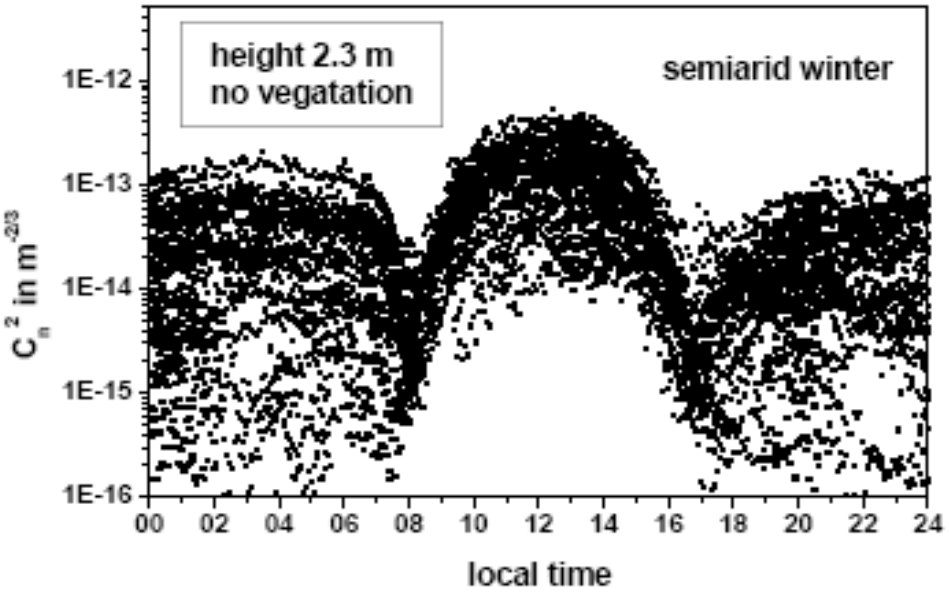
Blur is “range dependent”

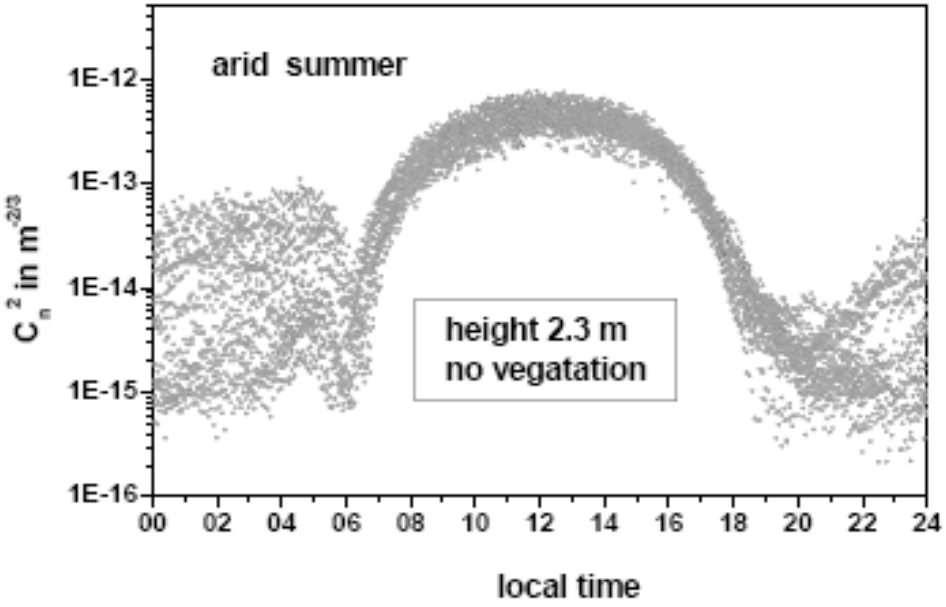
Cn2=5E-13m^(2/3), D=60mm



Turbulence

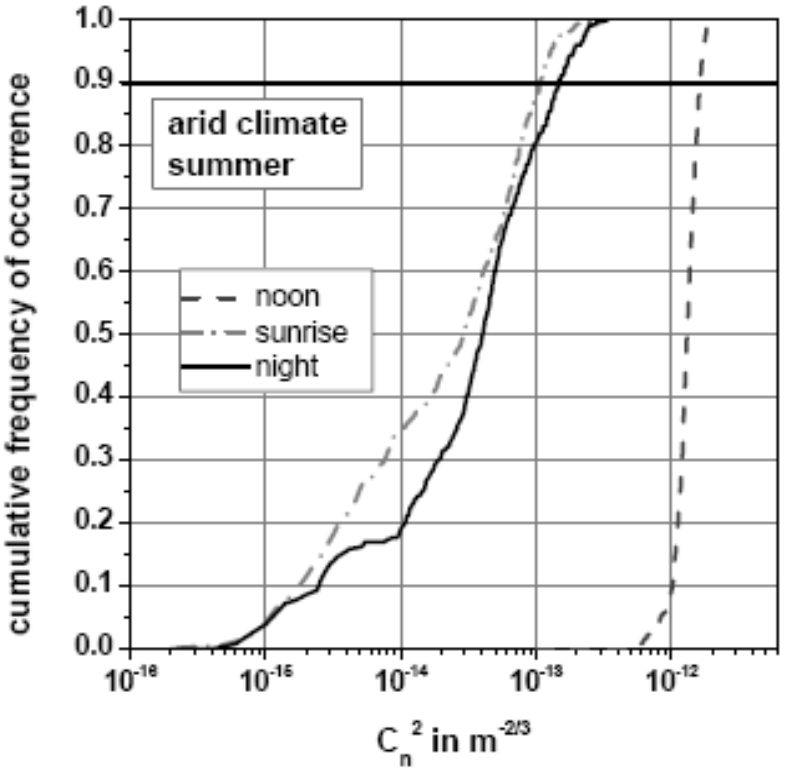
Weiss-Wrana's data showed a characteristic day/night variation when temperatures were moderate:

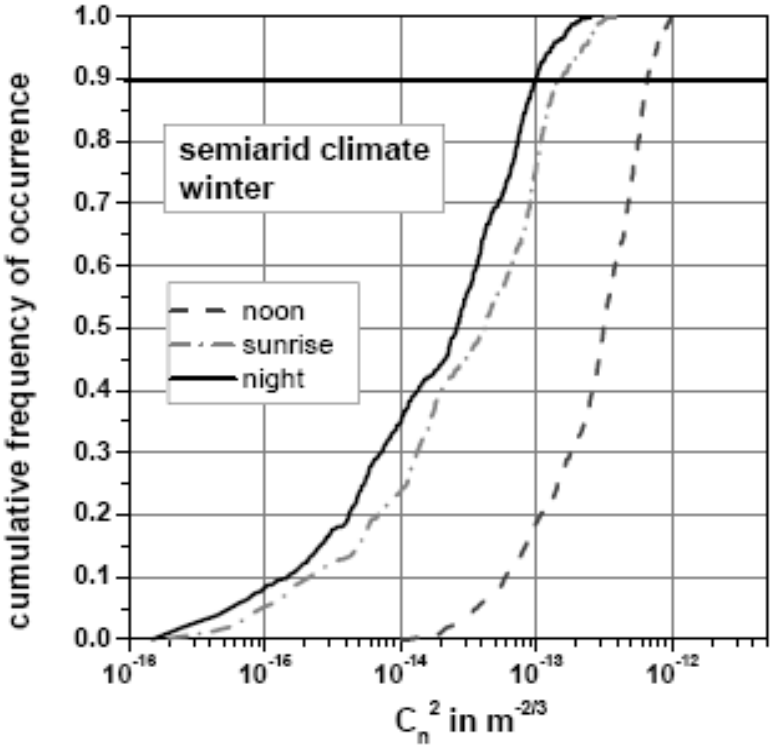




Turbulence

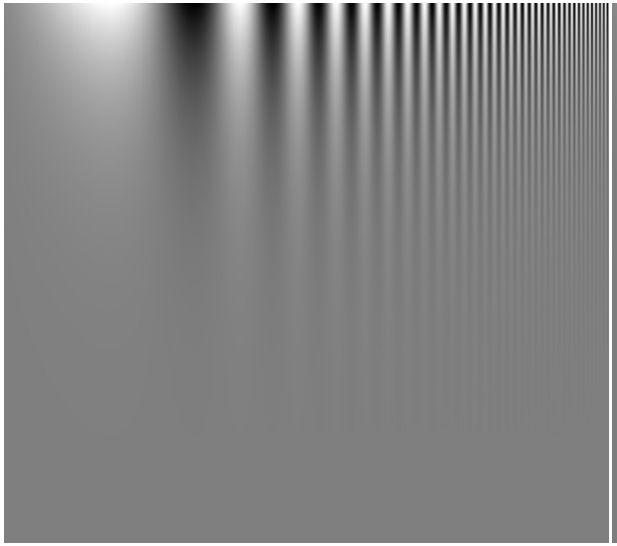
Sample frequency of occurrence plots derived from the raw C_n^2 data:





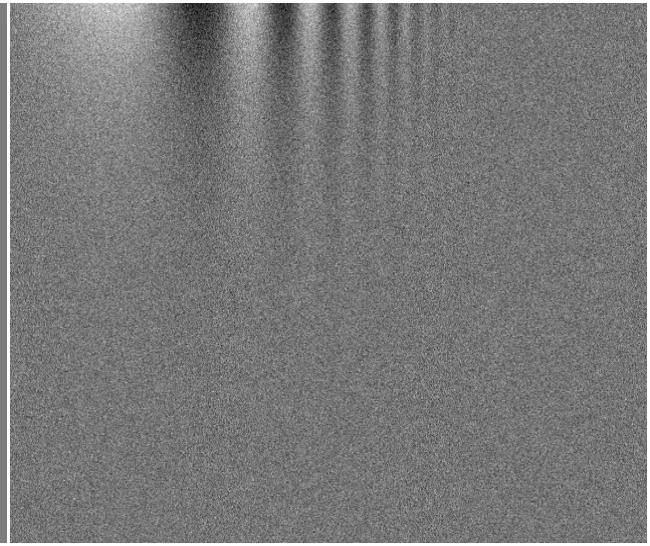
Contrast Threshold Function

Eye

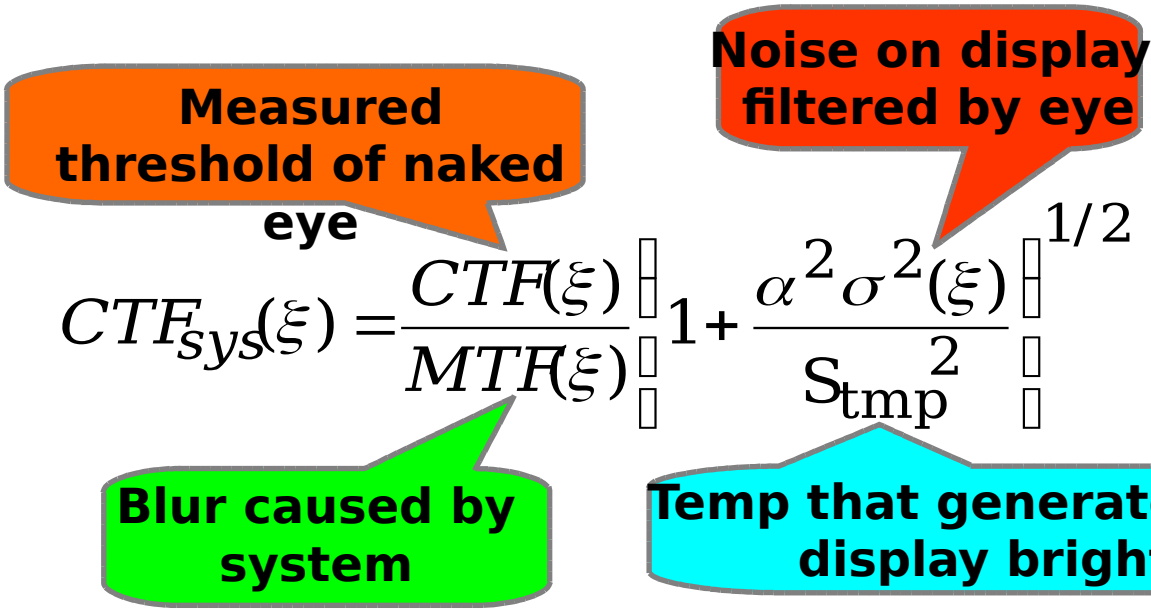


Eye + Blur

Eye + Blur + Noise



System CTF



ξ = spatial frequency in $(\text{milliradian})^{-1}$

MTF(ξ) is system modulation transfer function

$\sigma(\xi)$ = noise filtered by display & visual system in units of Kelvin

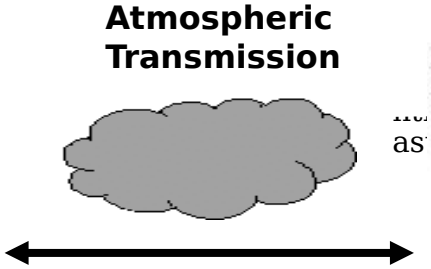
α is a calibration constant with units root-Hertz

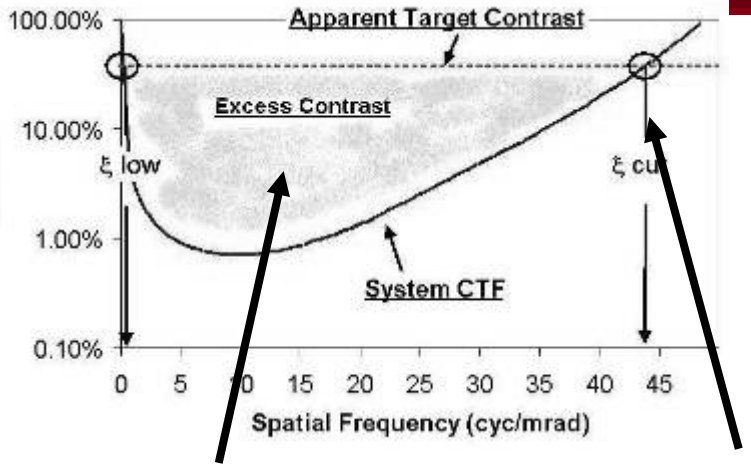
S_{tmp} units Kelvin (scene temperature that results in average display luminance)

Target Acquisition

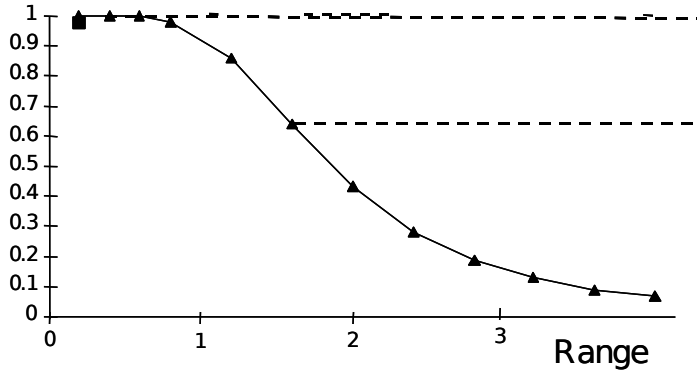
Source Contrast:

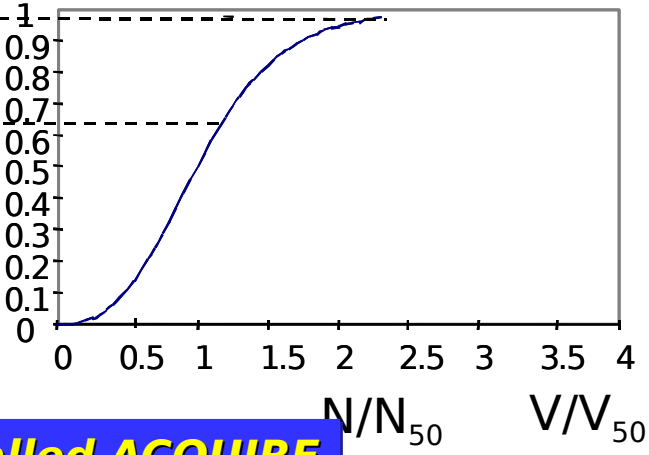
Char. Dim. $s = \sqrt{Area_{tgt}}$





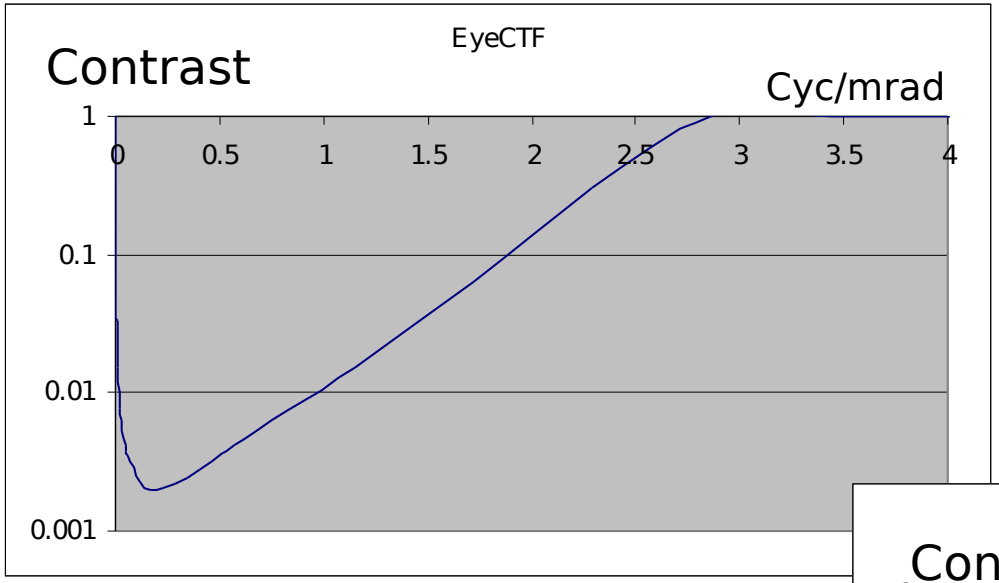
$$V = \int_{\xi_{low}}^{\xi_{cut}} \sqrt{\frac{C(\xi)}{CTF(\xi)}}\, d\xi \left[\frac{s}{R}\right] \quad \textbf{or} \quad N = \xi_{cut} \left[\frac{s}{R}\right]$$

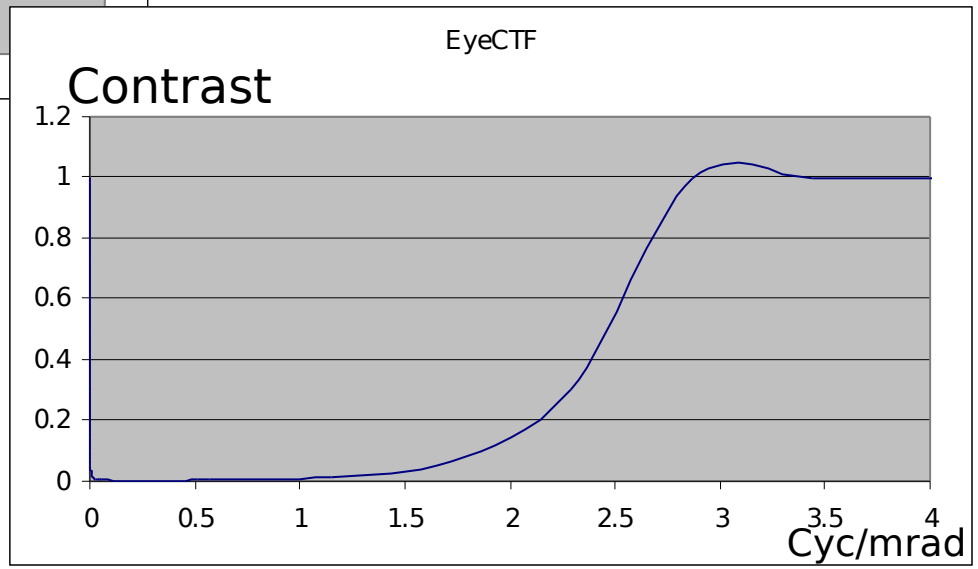




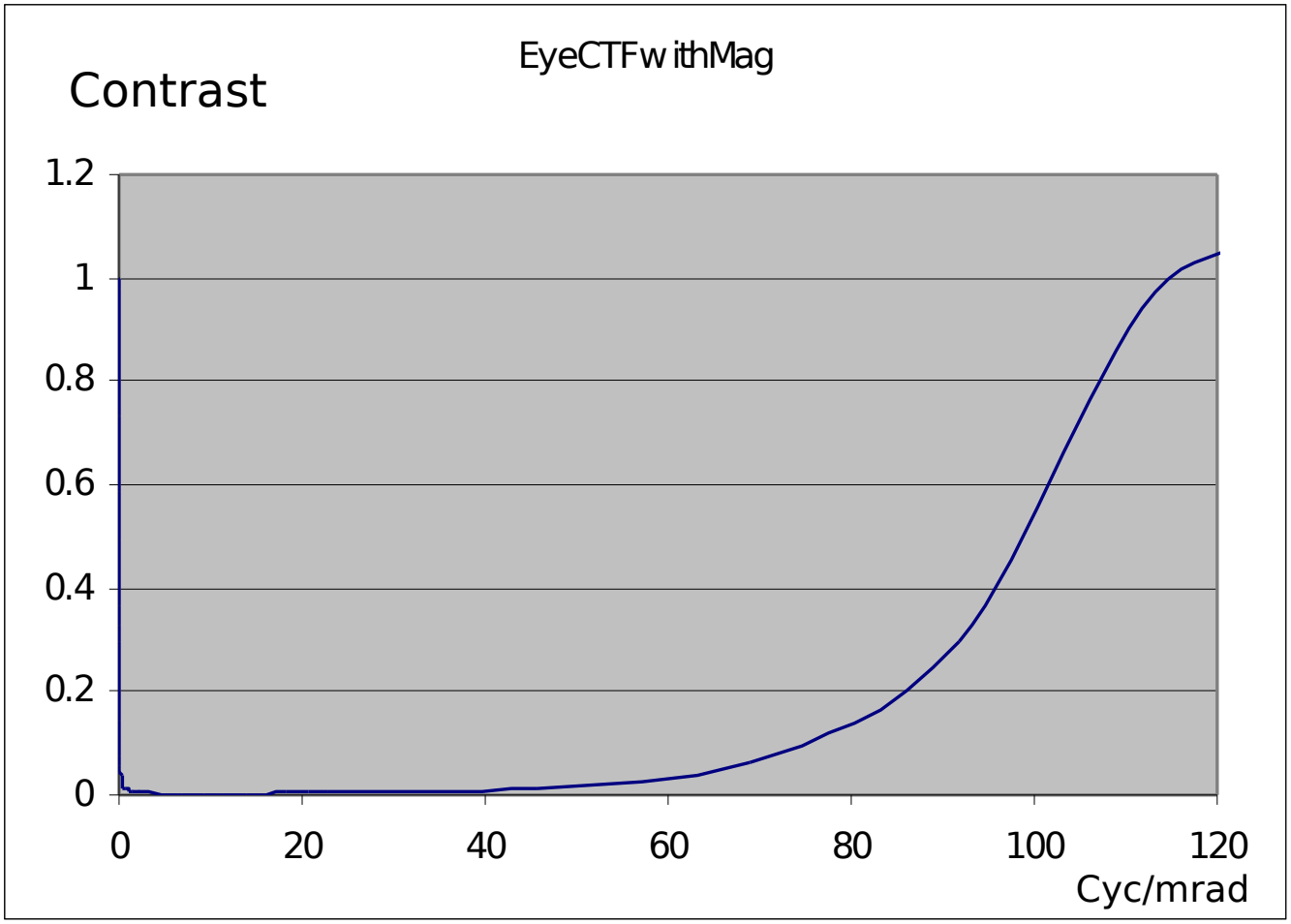
N50, and Limiting Frequency Version is Called ACQUIRE

Eye CTF


EyeCTF
Contrast
Cyc/mrad
1
0.1
0.01
0.001
0
0.5
1
1.5
2
2.5
3
3.5
4


EyeCTF
Contrast
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Cyc/mrad

Eye CTF With 40X Mag



Cycles on Face for 90% Prob ID

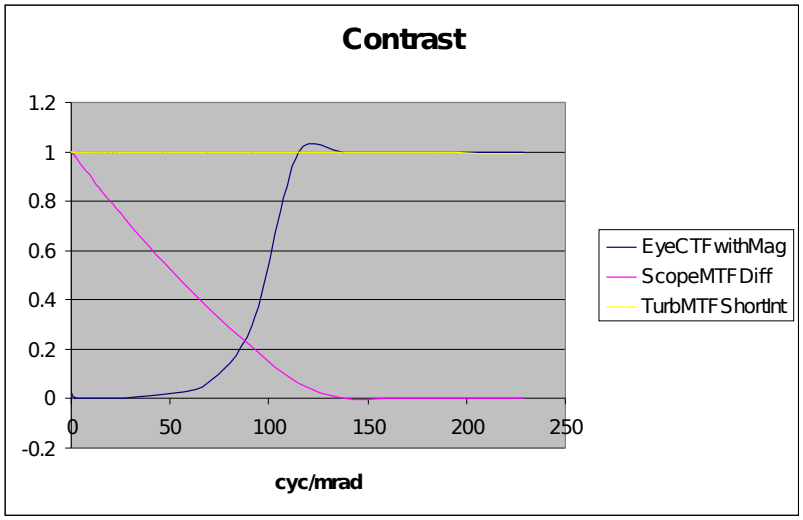
It has been roughly determined that a 40X, 60mm spotter scop
can ID a human face at 1000m

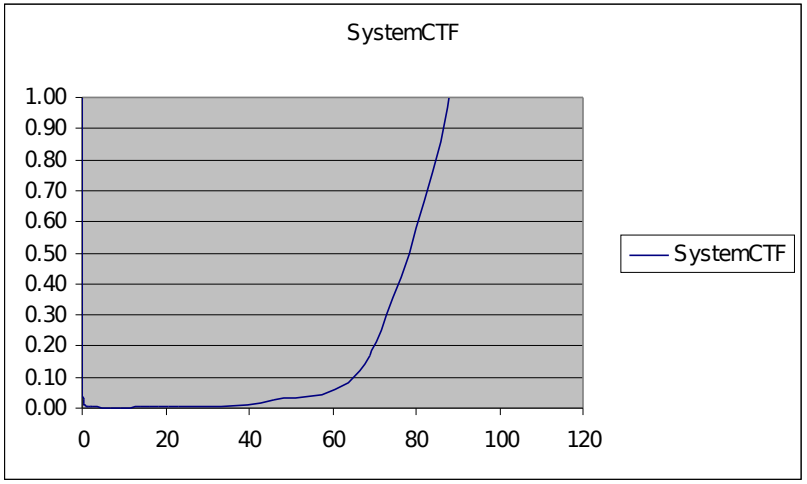
Facial Dimension is estimated at 7 inches by 9 inches
Equal to 406cm^2
Characteristic Dimension is 20cm

We will do this in terms of N50 and V50

This estimate was related to extremely low turbulence

90% Facial ID W/No Turbulence



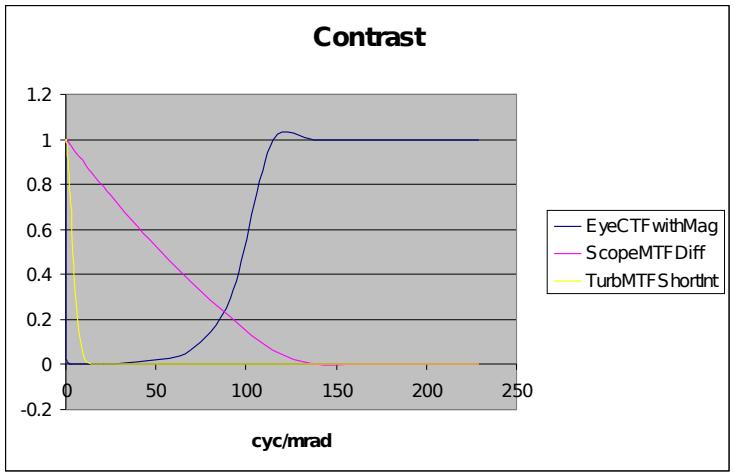


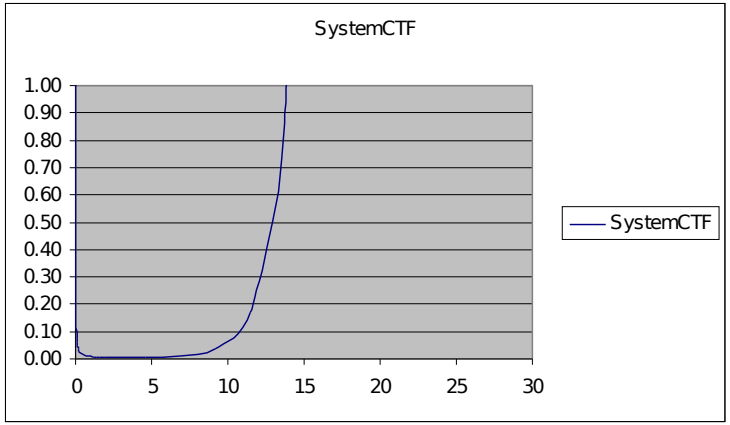
60mm Aperture
40X Mag
Lim Freq at 0.2 Contrast = 70 cyc/mra

N90
Frequency is 70 cyc/mrad*0.2mrads
= 14 cycles on target

V90
Frequency is 280cyc/mrad*0.2mrades
= 55 cycles on target

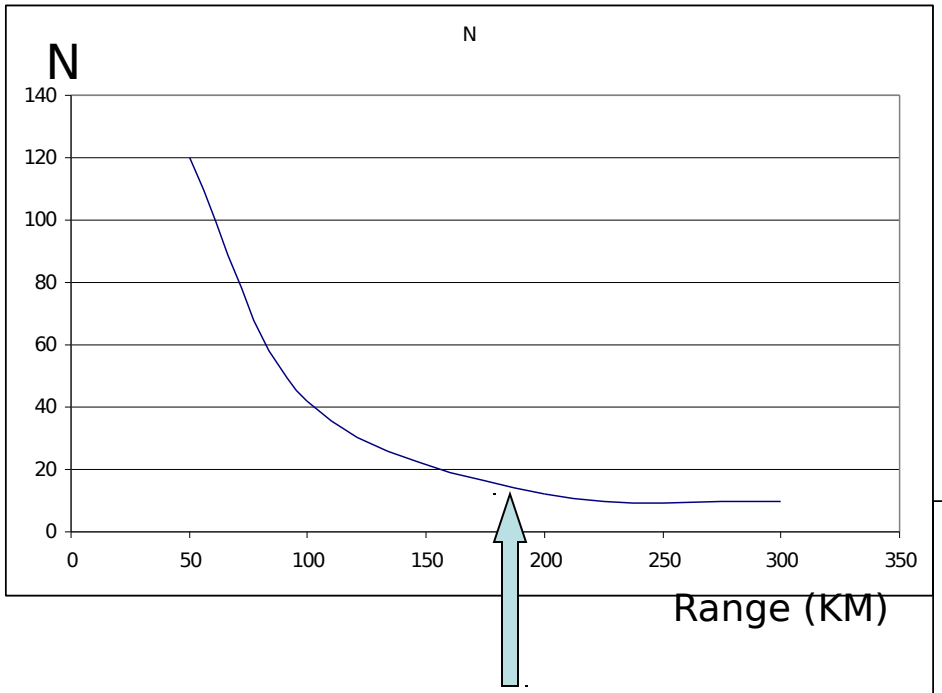
Range Prediction for 90% Facial ID W/5E-13 m(-2/3) CN2

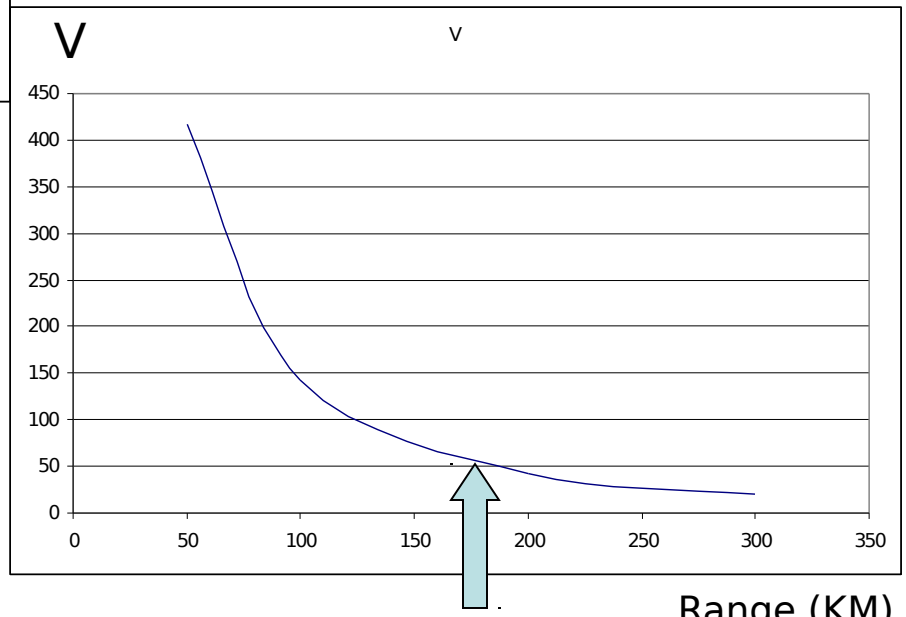




Note the Significant Reduction in the CTF of the System Due to the Turbulenc MTF (200 meters shown)

Range Prediction for 90% Facial ID W/5E-13 m(-2/3) CN2





Conclusion

- Demonstrates current day optic technology will support facial ID, BUT NOT in turbulence.
- Estimates resolution required to perform basic facial ID test (for BAA Preps).
- Possibly useful model in designing elements of the scope itself